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GENERAL SCIENCE.—*A list of one hundred popular books in science.*[1] Compiled by a committee of the WASHINGTON ACADEMY OF SCIENCES.

At the request of Dr. George F. Bowerman, Librarian of the Public Library of the District of Columbia, a committee of the ACADEMY has undertaken the compilation of a list of scientific books which can be recommended for popular use. The Editors believe it to be of sufficient interest to the members of the ACADEMY and other readers of the JOURNAL to warrant the preliminary publication of the report, particularly as it is hoped that criticisms and suggestions from readers may be brought forth and the list thereby improved. It is to be emphasized that the list is strictly tentative, and that neither the Committee as a whole nor any one member of it can assert that the books named are the very best for the purpose. It will be obvious also that broad areas of the field of science are hardly touched at all, and that the relative number of books treating of different subdivisions of science must not be taken to represent the relative importance of each subdivision or the relative activity of modern research therein. *Readability* is an essential criterion for selection, and books that are "readable," from the public's point of view, are very unevenly distributed as to subject-matter.

The first test for the kind of book that is desired for the list is this: Would the average reader who uses a public library, after beginning to read the book in question, read it through to the end and come back to the Librarian for another on the same subject? Such a book should be included. Or would he lay it down after a little while and turn to some other kind of book as being more interesting, and not return to the subject again? Such a book should not be included,

[1] Received August 25, 1921.

however accurate, thorough, and complete it might be from the standpoint of a specialist.

It is also desirable that the book should not be professedly a text-book, nor should it be written in text-book style; that is, it must not be a book intended primarily for the seeker after information regardless of whether the information be interesting reading or not. It is perhaps needless to add that it should have been written by an author who knows his subject thoroughly, and should not be so old as to be obsolete in its facts and speculations.[2]

The user of such a list may well be reminded at the outset that the field of science is not sharply divisible into little compartments labeled "Chemistry," "Botany," and the like. On the contrary, there is one vast field of human knowledge, and facts concerning any part of that field have a bearing on every other part. The usual subdivisions, which are those employed here, are not fundamental; they are largely accidental and have arisen merely as a matter of human convenience.

If we believe with Pope that "The proper study of mankind is Man" we may well begin with books about Man himself, rather than follow the austere and logical order laid down by philosophers, beginning with mathematics and ending with sociology. The natural order of human education is just the reverse, beginning with impressions of human nature and reaching formal logic and philosophy last, if ever. In this preliminary list, however, the Committee does not attempt to recommend any books in the fields of psychology, sociology, and related sciences, but begins with Man considered rather as a species or as an organism, suggesting the following books in anthropology and physiology:

[2] These specifications are not easy to meet. Popular scientific books of a class which might be described as "interesting if true" are not uncommon, but the production of such books seems to demand primarily a sufficient dearth of conscience and professional pride on the part of author and publisher. Others fall on the borderline between the merely "unorthodox" and the "misleading" or "misinforming." It is no great objection to a popular scientific book that its speculations are somewhat wild, provided its statements of fact and principle are based on knowledge and not on ignorance.

Librarians and interested readers can be depended upon to compile lists of scientific books that are interesting, but they have no good way of finding out which of these are reliable. It is here that the ACADEMY can do a service, for there are on the shelves and recommended in library lists books of popular science which, under even the most liberal of "pure food laws" for books ought to be labeled "misbranded" or "adulterated" if not "poisonous." They are particularly common in those branches, such as meteorology and anthropology, in which every man considers himself something of an expert.

MASON, O. T. *The origins of invention.* 419 pp. ("Contemporary Science Series," Walter Scott, London, 1895.) Although old, this book is thoroughly reliable and will remain authoritative for decades to come. It is readable and entertaining, and at the same time based on a wide knowledge of anthropology and ethnology.

MASON, O. T. *Woman's share in primitive culture.* 295 pp. (D. Appleton and Co., New York, 1894.) Like the preceding book by the same author, this work remains a standard. It will be particularly welcome to readers who have been irritated by the irresponsible pseudo-science that is sometimes written about the relative status of the sexes in primitive, as compared with modern, society.

OSBORN, Henry Fairfield. *Men of the Old Stone Age, their environment, life and art.* 545 pp., 268 illustr., 33 pp. of bibliography and index. (Charles Scribner's Sons, New York, 1915.) This book is a popular synthesis of the findings and opinions of many specialists, including the author himself, in the fields of archeology, paleontology, geology, anthropology and primitive art.

HADDON, A. C. *The study of man.* 410 pp. (G. P. Putnam's Sons, New York, 1898.) A reliable and readable work by one of the foremost ethnologists and anthropologists of Great Britain. It deals interestingly with the distribution of Man and his varieties over the Earth's surface.

KIDD, Dudley. *Savage childhood, a study of Kafir children.* 314 pp., 32 illustr. from photographs. (Adam and Charles Black, London, 1906.) This book is less general than the preceding but it is particularly attractive. The games, stories and songs of Kafir children as well as Kafir customs pertaining to children are described in a charming and instructive manner. The book is artistic rather than scientific but is a distinct addition to popular knowledge of anthropology and ethnology.

HOUGH, Walter. *The Hopi Indians.* 265 pp. (Torch Press, Cedar Rapids, Iowa, 1915.) This is one of the best examples available of descriptive anthropology applied to a particular group. It is entertainingly written, and the author's long experience in the field is a guarantee of its accuracy.

MCCOLLUM, E. V. *The newer knowledge of nutrition.* 199 pp. (The Macmillan Co., New York, 1919.) This book contains an authoritative, non-technical statement of the principles underlying proper human nutrition as developed from a great number of experiments and observations, some of the experiments having been carried out by the author and described by him in an interesting way in the book, with illustrations. The literature on the subject of nutrition has been surveyed and condensed reference is made to this extended field.

SHERMAN, H. C. *Food products.* 594 pp. (The Macmillan Company, New York, 1918.) The chemistry, physiology, availability and economics of human foodstuffs are authoritatively discussed in essentially nontechnical language.

Man shares with every other member of the animal and vegetable kingdoms that remarkable capacity, still a mystery to every investigator, whether biologist, chemist, or physicist—the capacity of reproducing his kind and handing down his qualities to his descendants The following books on heredity are standard works in this field

DARWIN, Charles. *The origin of species* (with additions and corrections from sixth and last English edition). 338 pp. (D. Appleton and Co., New York, 1917.) No collection of works on biology should be without this classic. The observations of Darwin are still the current material in biological discussion. His brilliant imagination, together with the thorough and painstaking way in which all conclusions are checked and tested without bias, cannot fail to impress the reader that the study of heredity is a noble and engrossing subject.

EAST, E. M., and JONES, D. F. *Inbreeding and outbreeding.* 285 pp. (Lippincott Co., Philadelphia, 1919.) Although confined to a restricted field, this work presents the most modern interpretation of the phenomena of inheritance in comprehensible form.

CASTLE, W. E., COULTER, J. M., DAVENPORT, C. B., EAST, E. M., and TOWER, W. L. *Heredity and eugenics.* 315 pp. (Chicago University Press, 1912.) A collection of lectures proposed for an audience not especially trained in biology. Although many important facts have come to light since these lectures were delivered, they give, in readable form, the general conceptions of heredity that are held by leading investigators.

MORGAN, T. H. *A critique of the theory of evolution.* 197 pp. (Princeton University Press, 1916.) The author is one of the foremost investigators of heredity. His work in the field of genetics, together with that of his students, has resulted in discoveries that rank with those of Mendel. This book, written for undergraduates, is semi-popular in style and although special emphasis is laid on the phases of the subject in which the author is especially interested, it introduces the reader to the important discoveries made in genetics.

CONKLIN, E. G. *Heredity and environment.* Third edition. 361 pages. (Princeton University Press, 1919.) Newer and technical aspects of a difficult science are not shunned in this treatise but the direct bearings of the results of recent studies in this field upon the welfare and the future of man are presented in a most readable manner.

GALTON, Francis. *Hereditary genius.* 390 pp. (D. Appleton and Co., New York, 1884.) Old, but emphasizes in a delightful way the most important side of genetics.

POPENOE, Paul, and JOHNSON, R. H. *Applied eugenics.* 459 pp. (Macmillan Co., New York, 1918.) A clear and forceful presentation of the bearing and importance of studies in heredity as applied to the human race.

Certain phenomena are common to all kinds of living organisms, whether "animals" or "plants." Reproduction and inheritance have already been spoken of, but there are also growth, and death, and standing behind them waiting to be explained in terms that satisfy the physicist as well as the biologist the fact of evolution:

THOMSON, John Arthur. *The wonder of life.* 658 pp. (A. Melrose, Ltd., London, 1915.) "An unconventional introduction to Natural History and Biology, taking broad views of the actual lives of living creatures and working inwards." A bookful of "wonders," not exploited for the curious, but all bringing their evidence to bear on general laws of life and its evolution.

HEADLEY, F. W. *Problems of evolution.* 373 pp. (Crowell and Co., New York, 1900.) The author is a skilled lecturer and introduces his book with an elementary chapter for the general reader, also avoiding technical terms throughout the work.

LOTSY, J. P. *Evolution by means of hybridization.* 166 pp. (M. Nijhoff, The Hague, 1916.) A brief and stimulating essay on the origin and transformations of living beings.

On the more purely descriptive side of the biological sciences there exists a wide variety of books. It is convenient to roughly divide the field into "zoology" and "botany," and the following readable books in each of these two subjects can be recommended:

In zoology:

BUCKLEY, A. B. *Life and her children.* 312 pp. (Appleton and Co., New York, 1881.)

BUCKLEY, A. B. *The winners in life's race.* 367 pp. (Appleton and Co., New York, 1883.)

These two books are elementary but fascinating, forming a delightful introduction to the study of invertebrate and vertebrate zoology, respectively.

In botany:

GANONG, W. F. *The living plant: a description and interpretation of its functions and structure.* American Nature Series. 478 pp. (Henry Holt and Co., New York, 1913.) A thoughtful and suggestive book by a leading American plant physiologist. Written in the form of an essay rather than the usual college text-book and designed to appeal to those interested in knowing how living things "work," rather than to professional botanists. Well illustrated.

OSTERHOUT, W. J. V. *Experiments with plants.* 492 pp. (The Macmillan Co., New York, 1905.) An introduction to plant physiology with descriptions of many ingenious experiments requiring only simple home-made apparatus. The author is one of the leading plant physiologists of the United States. The reader should take note, however, that much progress has been made in this branch since 1905.

SORAUER, Paul. *A popular treatise on the physiology of plants for the use of gardeners or for students of horticulture and agriculture.* Translation by F. E. Weiss. (Longmans, Green & Co., London, 1895.) This well-written and comparatively brief but highly authoritative work presents a very satisfactory treatment of the structure and nutrition of plants. It might be entitled "the plant at work." As the subtitle indicates, the practical application of the principles set forth is constantly in view.

LUBBOCK, John (Lord AVEBURY). *Flowers, fruits and leaves.* Nature Series. (Macmillan Co., New York, 1908.) A readable and suggestive little book by the well-known statesman and botanist.

A special field of botany is that devoted to the distribution of plants over the earth's surface—ecology:

HARDY, Marcel E. *The geography of plants.* 339 pp. (Clarendon Press, Oxford, 1920.) A short readable account of the distribution of vegetation over the surface of the Earth. It is concerned largely with distribution, and only to a slight extent with the relations of plants to their environment.

There are many books dealing in an interesting way with restricted groups of living organisms. Some describe the life of a given locality; some tell about the members of a certain family, wherever they may be found. It is much easier to make a list of good manuals

and information-books in this field[3] than to select a list of the type described in our specifications, but the following will serve as good introductions:

DARWIN, Charles. *Insectivorous plants.* 462 pp. (Appleton and Co., New York, 1896.) An extremely interesting book, and a classic for nearly fifty years. Darwin did his work so thoroughly and well that no one else has touched the subject since to add anything of importance.

TOWNSEND, C. W. *Sand dunes and salt marshes.* 311 pp. (Dana Estes and Co., Boston, 1913.) A very readable and interesting book, highly suggestive to anyone spending a vacation at the seashore. Contains much about plant and animal life, and the physiography of the shore region.

The zoologists have provided more abundantly the kind of books wanted for this list than have the botanists, though their subject matter is hardly more diverse. A sketchy view of their field, beginning with the mammals and coming down the scale to the protozoa, may be had from the following books:

STONE, Witmer, and CRAM, W. E. *American animals. A popular guide to the mammals of North America north of Mexico.* 318 pp. (Doubleday, Page and Co., New York, 1902.) Not simply a manual, but a good book to look through and read. It is abundantly illustrated with plates and halftones, and tells just the things about the mammals that the average reader who has met them in the woods or seen them in the "Zoo" is interested to know.

ROOSEVELT, Theodore. *African game trails.* 583 pp. (Charles Scribner's Sons, New York, 1910.) No American needs to be told that the late ex-president was one of the most versatile of men. Though some of his critics accused him of substituting vigorous assertion for calm argument his zoological writings have often proved to be more reliable than others with a greater appearance of erudition.

BEEBE, C. *Jungle peace.* 297 pp. (Henry Holt and Co., New York, 1919.) A combination of zoology and philosophic reflections which makes very interesting reading, written by a keen and scientifically trained observer.

CHAPMAN, Frank M. *Camps and cruises of an ornithologist.* 432 pp. (D. Appleton and Co., New York, 1908.) Bird books for nature lovers are abundant, but are usually written for a particular locality. This one of Chapman's can be read with interest and profit in any part of the United States, and its author is a recognized authority in his subject.

HERRICK, F. H. *The home life of wild birds.* 148 pp. (G. P. Putnam's Sons, New York, 1901.) Although the author's subtitle calls the book a description of "A new method of the study and photography of birds," it is much more than that. His methods are interestingly described, but are followed up with entertainingly written examples of the additions that anyone who is really interested can make to ornithological science.

FABRE, J. H. *Social life in the insect world.* (Translation by Bernard Miall.) 327 pp. (Century Co., New York, 1912.) It is difficult to select from Fabre's books. All of them might well be recommended for such a

[3] The preliminary circulation of this list has evoked so many requests for a list of reliable manuals which students in one branch of science can depend upon for information in other branches, that the publication of such a list is recommended to the attention of a future committee.

list as this. They are most interestingly written, and while they are not free from minor inaccuracies, no book dealing with so complex a subject as a living organism can hope completely to avoid that criticism.

PECKHAM, S. W., and PECKHAM, E. G. *Wasps, social and solitary.* 310 pp. (Houghton Mifflin Co., Boston, 1905.) A well written record of the habits of our common wasps. Mr. and Mrs. Peckham spent years in careful and patient observation, and have written some of our standard manuals, as well as this very popular work.

MAETERLINCK, Maurice. *The life of the bee.* (Translation by Alfred Sutro.) 427 pp. (Dodd, Mead and Co., New York, 1902.) The author is more widely known as a poet and dramatist than as a zoologist, but he is also a careful student and observer and has contributed in this work one of the reliable books in its field.

DARWIN, Charles. *The formation of vegetable mould through the action of worms.* 362 pp. (D. Appleton and Co., New York, 1892.) A model of the scientific method of attacking a biological problem.

BLATCHLEY, W. S. *Gleanings from nature.* 348 pp. (Nature Publishing Co., Indianapolis, 1899.) One of the few books that give a popular and at the same time accurate account of our common reptiles. The book contains also observations of many other animals and plants.

ABBOTT, Charles C. *Upland and meadow.* 397 pp. (Harper and Bros., New York, 1886.) A charming book by an author who devoted his life to the study of living organisms as they appeal to the "naturalist"—a type of scientist which has become, temporarily, we may hope, almost extinct.[4]

MAYER, Alfred G. *Sea-shore life.* 181 pp. New York Aquarium Nature Series. (A. S. Barnes and Co., New York, 1906.) A book intended for readers who may be unfamiliar with the technical terms in use among specialists. Every dweller or visitor at the sea-shore will find it of interest, though most of the illustrations are of species along the northern Atlantic coast of the United States.

Uncounted multitudes of species of living organisms have risen and then declined in past ages. Their study is far from being the dry subject that the word "bones" suggests:

LUCAS, F. A. *Animals of the past.* 258 pp. (McClure, Phillips and Co., New York, 1902.) A very entertainingly written book about a few of the better known or more remarkable of the extinct animals of the ancient world, written partly "to ease the strain on these venerable animals, caused by stretching them so often beyond their due proportions."

HUTCHINSON, H. N. *Extinct monsters and creatures of other days: a popular account of some of the larger forms of ancient animal life.* 329 pp. (Chapman and Hall, London, 1910.) The field selected by the author is that part of paleontology which is best adapted for arousing and holding the interest of the general reader. Technicalities have been omitted as far as possible. A fairly good idea is given of the progress of animal life through the geologic ages. Copiously illustrated, with many restorations.

[4] Good books of travel, exploration, and adventure written by scientists, or by persons who are keen observers of natural phenomena, are fairly numerous. Such are Thomas Belt's *The naturalist in Nicaragua* (306 pp., Dutton and Co., New York, 1911), and Lyell's *Travels in North America*, but as librarians usually place such books with "travel and description" or some similar classification, no attempt at a selection will be made here. The ACADEMY could do a service by preparing a list of reliable books of this kind.

There are not many hard and fast lines of division in science, but there is one that so far has not been wiped out—the line between "living" and "dead" matter. For the rest of our booklist we shall be dealing with sciences not primarily concerned with organic life. The first general group of these is comprehended under the term "geology," including all the sciences which are concerned with the Earth as a whole, with the constitution and structure of its surface and its interior, and with the existing evidences of its past history:

DWERRYHOUSE, Arthur R. *Geology.* 301 pp. ("Romance of Reality" Series. T. C. and E. C. Jack, London and Edinburgh, about 1917.) This up-to-date book is attractively written in clear and simple language for the general reader by a competent geologist. The larger part of it is devoted to the description of an imaginary geological excursion to a hypothetical country. Thus the book loses something of its force from the fact that its descriptions are not taken from actually known and named localities. In the course of the supposed excursion many interesting geologic facts are brought out and are made to bear directly upon the history of the country and upon the development of its natural resources. Methods of field study are also shown.

SEELY, H. G. *The story of the Earth in past ages.* 190 pp. (Appleton and Co., New York, 1910.) An elementary little book, with references mostly to British geology, but containing much matter of general interest.

COLE, Grenville A. J. *The changeful Earth.* 223 pp. (Macmillan and Co., Ltd., London, 1911.) "Inspiration rather than information" is the keynote of the series of which this little book is a member, and it is most effectively carried through, yet without sacrifice of accuracy.

LULL, R. S., and others. *The evolution of the Earth and its inhabitants.* 208 pp. (Yale University Press, New Haven, 1918.) A very readable book, well illustrated, and written by a group of skilful and inspiring lecturers (Barrell, Schuchert, Woodruff, Lull, and Huntington).

BALL, Robert S. *Time and tide.* Third edition. 192 pp. (Society for Promoting Christian Knowledge, London, 1895.) Justly described as a "Romance of the Moon." Two lectures in popular language devoted to the evolution of the Earth-Moon system.

SPURR, J. E., Editor. *Political and commercial geology and the world's natural resources.* 562 pp. (McGraw-Hill Book Co., New York, 1920.) The political and commercial aspect of Earth-science is usually put under the heading of "geography." This book is in that sense a geographic book, for it tells of the location and accessibility of the world's mineral supplies rather than of their origin and geologic relationships. Mr. Spurr is well fitted to present this readable and accurate account of the subject by his training as an editor, mining geologist, and member of the Government's boards on war minerals.

BRIGHAM, Albert P. *Geographic influences in American history.* 285 pp. Chautauqua Home Reading Series. (Chautauqua Press, Chautauqua, New York, 1903.) A popular account by a well-known American geographer. The treatment is unbiased and scientific; the presentation is orderly, thorough and mainly accurate, though weak in some details; the style readable, not catchy, but attractive and stimulating.

Water is perhaps the most active of all the agents that are continually modifying the surface of our changeful Earth:

BONNEY, T. G. *The work of rains and rivers.* 144 pp. Cambridge Manuals of Science and Literature. (Cambridge University Press, England, 1912.) This is practically the only modern book in its field. It can be called neither abstruse nor popular, but is written in fairly simple language suitable for the reader of average education, and is a logical, thorough, and accurate presentation.

CORNISH, Vaughan. *Waves of the sea and other water waves.* 374 pp. (Open Court Publishing Co., Chicago, 1911.) A well written book in non-technical language, beautifully illustrated, dealing in descriptive form with the size, speed, and action of waves in the sea and in rivers.

Volcanoes, although they represent only one among dozens of agents that are active in altering the Earth's surface, have always focussed popular attention upon themselves by the amount of noise they can make and the amount of human destruction they can do in a short time:

BONNEY, T. G. *Volcanoes, their structure and significance.* 321 pp. (G. P. Putnam's Sons, New York, 1899.) By taking up in narrative style the characteristics of some "live" volcanoes the author leads the reader on to do some thinking and speculating for himself as to the cause of volcanicity—and there is still much room for study though important additions to our knowledge have been made since this book was written. Nevertheless, the new facts have by no means rendered this excellent work obsolete.

RUSSELL, Israel C. *Volcanoes of North America.* 346 pp. (Macmillan Co., New York, 1897.) The author calls his book "a reading lesson for students of geography and geology" but it is more than that. It is a very readable account of some of our own volcanic mountains, which are already familiar to most Americans but which gain added interest through comparison with the volcanoes of other countries and through discussion of the agencies which built them.

No subject in all the range of man's interests is more commonly used in introducing friendly conversation and in maintaining it than the weather. Well-told information about the atmosphere and the causes of meteorological phenomena, such as is contained in the books listed below, cannot fail to add to its interest:

HARRINGTON, Mark W. *About the weather.* 246 pp. (D. Appleton and Co., New York, 1899.) Attractively written. Antedates many interesting discoveries, but otherwise is one of the best of the popular works on meteorology.

DICKSON, H. N. *Climate and weather.* 256 pp. (Williams and Norgate, London, 1911.) Brief sketches on special topics, interestingly done.

LEMPFERT, R. G. K. *Weather science.* 94 pp. (T. C. and E. C. Jack, London, 1912.) Chiefly a very brief popular account of weather forecasting.

WARD, R. de C. *Climate, considered especially in relation to Man.* Second edition. (G. P. Putnam's Sons, New York, 1918.) The best book on climate addressed to the general reader.

TALMAN, C. F. *Realm of the air.* (P. F. Collier and Son, 1921.) Interesting, accurate and up-to-date.

Besides being blanketed with a layer of air, which is the domain of meteorology and "the weather," the Earth is also covered in large part with a thin layer of water, from a few inches to several miles deep—the ocean. The geography of the ocean, the science which treats of the distribution, the physical properties, and the tides and currents of the ocean is known as oceanography:

MURRAY, John. *The ocean.* 256 pp. (Henry Holt & Co., New York, about 1913.) An interesting, non-technical, yet thoroughly reliable account of the methods, instruments and results relative to the depths, temperatures, physical properties, tides, currents and plant and animal life in the ocean.

The structural units of the solid earth—the "bricks" of which it is built—are the rocks, whose composition, properties, and origin form the subject matter of petrology:

COLE, Grenville A. J. *Rocks and their origins.* 175 pp. Cambridge Manuals of Science and Literature. (Cambridge University Press, England, 1912.) Neither abstruse nor popular, but adapted to a well-informed reader rather than a beginner. The treatment is unbiased and thoroughly scientific, and covers the whole field, though briefly. It is logical, thorough, accurate, and stimulating; readable, but not catchy. There is no other book in the field of just the same sort, for comparison.

The constituent crystals or particles which make up the rocks (including the valuable ores) form the subject of "mineralogy"—from one point of view a branch of chemistry:

BENNETT, Lee F. *Rocks and minerals.* Third edition. 88 pp. (Bogarte Book Co., Valparaiso, Indiana, 1914.) An excellent little elementary book, describing in an interesting way 40 minerals and 40 rocks. Suited to give the general reader with a minimum of time at his disposal a good idea of the scope of the sciences of mineralogy and petrology.

GRATACAP, Louis P. *A popular guide to minerals.* 330 pp. (D. Van Nostrand Co., New York, 1912.) A splendidly illustrated work, based on the collections in the American Museum of Natural History in New York City. The text is not up to the standard of the plates, being rather clumsily put together, although reasonably accurate and elementary in most places. Will appeal to the users of books who gain more from illustrations than from text matter.

The oldest of the sciences, and still the one with the most permanent popular appeal, notwithstanding the fact that its 5000-year competitor from the field of superstition—astrology—is still active, is astronomy:

ABBOT, Charles G. *The sun.* 448 pp. (D. Appleton and Co., 1911). The best book on the subject of the Sun; readable, though technical in places.

BALL, Robert S. *The story of the heavens.* 556 pp. (Cassell and Co., London, 1892.) Delightfully written, and in popular language.

DYSON, F. W. *Astronomy.* 247 pp. (E. P. Dutton and Co., New York, 1918.) Elementary, yet thoroughly reliable.

HALE, George E. *The study of stellar evolution.* 252 pp. (University of Chicago Press, 1908.) An interesting, well illustrated, and authoritative summary of results relating to the constitution of the stars and the Sun.

LEWIS, Isabel M. *Splendors of the sky.* 343 pp. (Duffield and Co., 1920.) Popular, accurate, and up-to-date.

MCKREADY, Kelvin. *A beginner's star book.* 148 pp. (G. P. Putnam's Sons, 1912.) Many fine illustrations.

TURNER, H. H. *A voyage through space.* (Society for Promoting Christian Knowledge, London, 1915.) Pleasingly written and reliable.

The Adolfo Stahl lectures in astronomy. 257 pp. (Stanford University Press, California, 1919.) Twelve lectures on modern astronomy by members of the Mount Wilson and Lick Observatory staffs. Accurate, interesting, and nontechnical.

The properties of matter without regard to its particular form make the subject matter of physics and chemistry. The carbon in a star has the same interest to the chemist and the physicist as the carbon in a tree-trunk or in a diamond. But it is impossible to write a definition that will divide physics from chemistry and still include under each all that we commonly understand by the two terms. In a general way, the chemist is interested in the composition of things, the physicist in their qualities. The titles of a few chemical books follow.[5]

SLOSSON, E. E. *Creative chemistry.* 311 pp. (Century Co., New York, 1920.) A very interesting and readable book, showing particularly the important place of chemistry in modern industry and in warfare. It is a book *about* chemistry and what it can do, rather than a book *of* chemistry, but can be recommended to the general and technical reader alike.

HENDRICK, Ellwood. *Everyman's chemistry.* 374 pp. (Harper and Bros., New York, 1917.) This book is specifically "designed for those who declare that they do not know anything about the subject."

DUNCAN, Robert Kennedy. *The chemistry of commerce.* 263 pp. (Harper and Brothers, New York, 1907.) An interesting interpretation of various phases of modern industrial chemistry.

MARTIN, Geoffrey. *Modern chemistry and its wonders.* 358 pp. (D. Van Nostrand Co., New York, 1915.) A description in non-technical language of some of the striking modern advances in chemistry.

Although the chemist has made contributions to almost every other portion of the field of science, it remains unfortunately true that most of his books are written for specialists and not for the general reader. The "physico-chemical" and "physical" portions of the field of physics and chemistry are not quite so lacking in readable books; the titles of some of these follow:

SODDY, Frederick. *Matter and energy.* 255 pp. (Henry Holt and Co., New York, 1912.) This is one of the best available accounts of fundamental physical and chemical principles. It is very brief and comprehensive, yet authoritative.

[5] Acknowledgments are due to the American Chemical Society's committee on chemical reading courses, of which W. A. HAMOR is chairman. This committee has published a full and well annotated list of books in all branches of chemistry. See Journ. Ind. Eng. Chem. **12**: 701, 806. 1920.

TYNDALL, John. *Fragments of science.* Fifth edition. 589 pp. (D. Appleton and Co., New York, 1884.) Though now fifty years old, these spirited essays by the most ardent proponent of the scientific method remain essentially correct and only the more firmly established by the later progress which has amplified our knowledge in the variety of fields touched upon.

EINSTEIN, Albert. *Relativity.* Translation by R. Lawson. 168 pp. (Methuen, London, 1920.) As simple an account as is readily possible of the old and new theories of relativity by the originator and leader of this revolutionary school of thought.[6]

WHETHAM, W. C. D. *The recent development of physical science.* 347 pp. (Blakiston's Son and Co., Philadelphia, 1909.) One of the Cambridge school of physicists tells of the work on the borderland of physics and chemistry during the important period to which he and his colleagues made valuable contributions.

AMES, Joseph S. *The constitution of matter.* 242 pp. (Houghton, Mifflin and Co., Boston, 1913.) Professor Ames' long and varied experience and his close association with developments of modern physics enabled him to produce this valuable book, which combines comprehensiveness in subject matter with simplicity of expression.

FLEMING, J. A. *Waves and ripples in water, air, and aether.* 299 pp. (Society for Promoting Christian Knowledge, London, 1902.) This book is old but much of the field which it covers has not changed in recent years. It represents a course of Christmas lectures delivered to a "juvenile audience" at the Royal Institution, London. It is a most readable, instructive, and delightful book.

PERRY, John. *Spinning tops.* 136 pp. (Society for Promoting Christian Knowledge, London, 1901.) This popular lecture stimulates the imagination by illustrating both the wealth of interesting phenomena connected with a commonplace toy and the elegant simplicity with which the science of mechanics unifies these effects.

MILLER, Dayton C. *The science of musical sounds.* 286 pp. (Macmillan Co., New York, 1916.) This book, written by one of the foremost authorities in America, is very readable and particularly strong on the experimental side.

BRAGG, William. *The world of sound.* 203 pp. (Bell and Co., London, 1920.) A very well done and up-to-date treatment of a branch of physics that appeals to everyone. The material was prepared for a juvenile audience, the most difficult of all audiences to write for.[7]

MICHELSON, A. A. *Light waves and their uses.* 166 pp. (University of Chicago Press, 1903.) This is a readable popular account of the applications of light waves to the most delicate and refined scientific measurements. The author is a universally recognized leader in this field of science and the examples which he quotes of the conquest by the human mind of the realm of the "infinitely little" are (although he does not say so) in large part the result of his own efforts.

[6] This book does not fully fit the specifications in the early paragraphs of this list, but neither does any other of the flood of books and essays on relativity. The reader is not likely to be any better off for having read "Einstein made easy" before reading Einstein himself.

[7] Agassiz required of his students in each department of study "first a monograph, second a scientific lecture, third a popular lecture, fourth, a simple child's tale." SHALER, *Autobiography* (1909), p. 103.

ABNEY, W. de W. *Colour measurement and mixture.* 207 pp. (Society for Promoting Christian Knowledge, London, 1891.) In spite of the age of this book, the subject is one which has not suffered as much change as most of the branches of physics, and the book, which deals with the principles and measurements underlying color sensation, is well worth reading at the present time.

BOYS, C. V. *Soap bubbles: their colours and the forces which mould them.* 190 pp. (Society for Promoting Christian Knowledge, London, 1920.) This book, written by a man noted for his skill in devising experiments, contains a very interesting account of the properties of soap bubbles, and describes a large number of interesting experiments which may be made with them. (See also his companion book *Splash of the drop.*)

SODDY, Frederick. *The interpretation of radium.* 284 pp. (G. P. Putnam's Sons, New York, 1912.) A readable non-technical account of the subject by one of the pioneers in this field.

Mathematics is not ordinarily considered a subject to arouse popular enthusiasm, yet it is full of human interest and is a constantly growing and developing science. The following books will give an insight into its variety and interest:

CONANT, Levi Leonard. *The number concept, its origin and development.* 218 pp. (Macmillan Co., New York, 1896.) An interesting and readable account of the probable origin and nature of the concept of number, with a description of number systems, past and present, among different races of mankind.

WHITEHEAD, A. N. *Introduction to mathematics.* 256 pp. (Home University Library, Henry Holt and Co., New York, 1911.) A brief survey of the principal topics treated of by mathematics, handled in a popular way.

YOUNG, John Wesley. *Lectures on the fundamental concepts of algebra and geometry.* (Macmillan Co., New York, 1911.) An excellent elementary treatment of the subject.

SHAW, James Byrnie. *Lectures on the philosophy of mathematics.* 206 pp. (Open Court Publishing Co., Chicago, 1918.) An unexcelled elementary survey of the entire field of mathematics, including content, principles, methods, significance, and nature of mathematics, with references to literature. Although the treatment is popular and readable, a considerable knowledge of mathematics is required for a full appreciation of this work.

DE MORGAN, Augustus. *On the study and difficulties of mathematics.* 288 pp. (Open Court Publishing Co., Chicago, 1902.) A classic.

A wealth of material is at hand in the history of science from which the following are selected, though the choice of only a few is difficult:

LIBBY, Walter. *An introduction to the history of science.* 288 pp. (Houghton Mifflin and Co., Boston, 1917.) Well-written essays on a few selected topics of the history of science. Perhaps the best elementary introduction to the subject.

SEDGWICK, W. T., and TYLER, H. W. *A short history of science.* 474 pp. (Macmillan Co., New York, 1917.) The most comprehensive, if not the most accurate, elementary English book on the subject.

WHITE, Andrew D. *A history of the warfare of science with theology in Christendom.* 2 volumes. 415 and 474 pp. (D. Appleton and Co., New

York, 1896.) An excellent book treating a delicate subject with tolerance, kindness and wisdom.

SMITH, David Eugene. *Number stories of long ago.* 136 pp. (Ginn and Co., Boston, 1919.) Stories on the history of arithmetic written for *children.* Accurate and entertaining. Probably the only book on the history of science which was written especially for children.

BERRY, Arthur. *A short history of astronomy.* 440 pp. (Charles Scribner's Sons, New York, 1910.) Apparently there is no difference between this edition and a previous one published in London in 1898. Perhaps the best general elementary textbook. A very good introduction to the subject.

THORPE, Edward. *History of chemistry.* 2 volumes, 185 and 190 pp. (G. P. Putnam's Sons, New York, 1909–10.) Less complete but more elementary and far more easy to read than Ernst von Meyer's standard book.

GEIKIE, Archibald. *The founders of geology.* 289 pp. (Macmillan and Co., London, 1897.) The book embodies a series of lectures delivered by this distinguished English geologist before students of Johns Hopkins University. It is a charmingly written account of the beginnings of geological science and of the principal workers in that subject down to the latter half of the nineteenth century. Only European and British geologists are considered. The book is intended for the mature reader who knows something of geology, but it may be enjoyed as well by those who have no technical knowledge of the subject.

MERRILL, George P. *Contributions to the history of American geology.* 546 pp. Part of Report of U. S. National Museum for 1904. (Washington, 1906.) An interestingly written series of sketches of the leaders in American geology since its earliest days, well illustrated, and enlivened with anecdotes and comments. (A new edition is in preparation.)

LOCY, William A. *Biology and its makers.* 477 pp. Third edition, revised. (Henry Holt and Co., New York, 1915.) Good introduction; simple, clear and entertaining.

PHYSICS.—*The wave lengths of X-rays.*[1] RALPH W. G. WYCKOFF, Geophysical Laboratory, Carnegie Institution of Washington. (Communicated by Arthur L. Day.)

It is commonly assumed that the length of X-rays has been uniquely and definitely determined from the study of the structures of crystals. In the following discussion it will be shown, taking the case of sodium chloride as an example, that with the *existing* knowledge it is impossible to determine definitely the structure of any crystal in advance of a knowledge of the wave length of X-rays. Viewed then from this position only, the problem of the length of X-ray waves and of the structures of crystals becomes indeterminate and recourse must be had to other sources of information.

The customary method of determining the wave length of X-rays.—The wave length of X-rays has been determined through the following course of reasoning.[2] If a crystal is considered as composed of a

[1] Received June 16, 1921.

[2] W. H. and W. L. BRAGG. *X-rays and crystal structure.* (London, 1918.)

regular and orderly repetition of a certain grouping of atoms throughout space (as seems entirely permissible), and if we assume the correctness of the Laue theory[3] that the atoms in this crystal act as diffracting centers of a three-dimensional diffraction grating, then it follows that the wave length of the X-rays diffracted by this crystal, the "spacing between like planes" in the direction of the diffraction, and the angle of the diffraction effect are connected by the familiar expression

$$n\lambda = 2d \sin \theta \qquad (1)$$

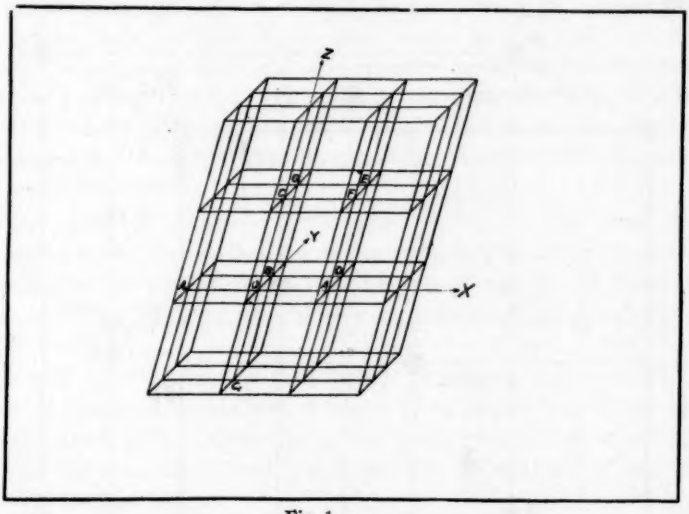

Fig. 1.

where n is the "order" of the reflection,

λ is the wave length of the diffracted X-rays,

d is the "spacing," that is, the distance between like planes in the chosen direction, and

θ is the angle of the diffraction.

In figure 1 *ADEFCGBO* represents the unit cell which is repeated along the axes of coordinates in a cubic crystal. The length of the side of this unit cube, AO, is d_{100}, the "spacing" against the cube face. The volume of this unit is then

$$V = (d_{100})^3 = \frac{mM}{\rho} \qquad (2)$$

where M is the weight of one chemical molecule of the substance,

[3] M. LAUE. Ann. Phys. 41: 971. 1913.

m is the number of these molecules in the unit,
ρ is the density of the crystal, and
V is the volume of the unit.

In this expression the density is known and the value of M is simply the molecular weight of the salt multiplied by the weight of an atom of hydrogen, which has been shown to be close to 1.64×10^{-24} grams. The other term upon the right hand side of this equation, m, can be known, however, only when the crystal structure of the salt is also known.

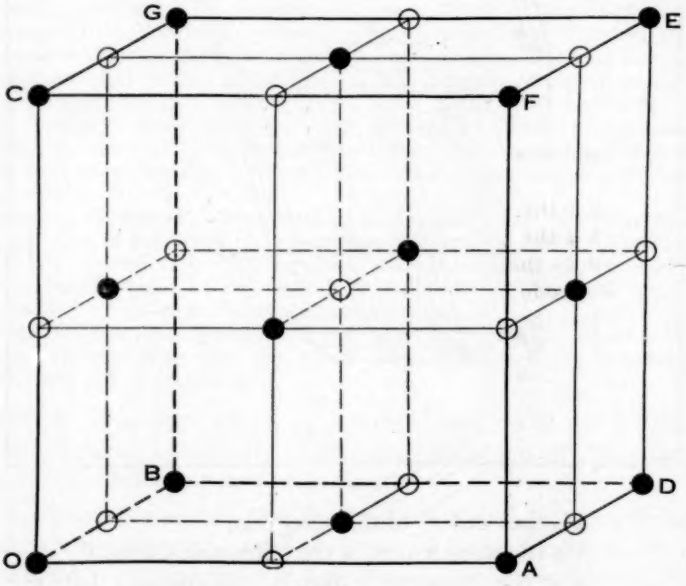

Fig. 2.

In first studying the wave lengths of X-rays the alkali halides were investigated, and of these the one which is from all points of view the most satisfactory to treat is sodium chloride. Since no information immediately useful for the present purpose can be obtained from a consideration of any other available crystals, it will be permissible to limit attention to this one salt.

The only data for establishing the structure of sodium chloride which are truly independent of assumptions more or less tacitly based upon an imagined structure of some crystal are (1) the observation (from Laue photographs) that only planes all of whose indices are odd are

found to give effects in what must correspond with the first order region, and (2) the confirmatory observation (from spectrometer measurements) that the first observable reflections from the (100), (110) and (111) faces stand in the ratio of

$$1 : \frac{1}{\sqrt{2}} : \frac{2}{\sqrt{3}}$$

The familiar "sodium chloride arrangement" (Fig. 2), with four chemical molecules associated with the unit cell, is in agreement with the above data, so that it has been taken as the structure of this crystal. Accepting such an identification as correct, a substitution of $m = 4$ in expression (2) yields d_{100}, and since the value of n is also directly determinable from a knowledge of the crystal structure, it is but a step to obtain the wave length of the X-rays (diffracted through the angle θ).

Other possible structures for sodium chloride.—The most serious objection to this determination of the wave length of X-rays obviously rests in the implied statement that because it agrees with these rather meager data, the "sodium chloride arrangement" is the correct one for this salt.

It will now be shown that other structures are possible. The effect of this observation will of course be to render this determination of the wave length of X-rays based upon the study of the structure of a crystal indeterminate (and along with it all determinations of the structures of crystals).

A factor which gives the effect of phase differences between the waves scattered by the atoms in any arrangement and which is therefore proportional, under certain conditions, to the intensity of the X-rays seemingly "reflected" by a plane of atoms can be written as[4]

$$I \propto \Sigma_m[\rho_m \cos 2\pi n (hx_m + ky_m + lz_m)]^2 + \Sigma_m]\rho_m \sin 2\pi n (hx_m + ky_m + lz_m)]^2,$$

where I is the intensity of reflection from planes hkl having the same relative spacings,

ρ is the scattering power of the atom m whose coordinate position is $x_m y_m z_m$, and

n is the order of the reflection.

[4] RALPH W. G. WYCKOFF. Amer. Journ. Sci. 50: 317. 1920.

The summation is to be taken over each atom in the unit cell. The spacings between like planes in a simple cubic lattice (Fig. 1) is proportional to

$$\frac{1}{\sqrt{h^2+k^2+l^2}} \qquad (1)$$

where h, k, and l are the indices of the plane.

With the aid of these two expressions, and *without* any precise knowledge of the "laws" of scattering, it is possible to determine the ratio of the spacings between like planes to be observed from any arrangement of atoms.

Every such structure which possesses complete (holohedral) cubic symmetry must be either a general or a special case of one of the ten space groups O_h^{1-10}. The ratio of the spacings to be observed from each of these space groupings for the (100), (110) and (111) planes has been calculated.[5] Of these ten groups but one, O_h^5, shows the sequence observed for sodium chloride. Any number of conceivable structures for sodium chloride can be developed from this space group by simply assigning different coordinate values to the positions of the sodium and chlorine atoms; and except for very special values of these coordinates the ratio of the spacing from the three planes under discussion will always be the same as that experimentally observed for sodium chloride.[6] For the sake of simplicity of illustration the least complicated of the special cases of this space group will be treated. The three special cases containing the fewest number of molecules within the unit cell are:[7]

Four equivalent positions:

(1) 000; $\quad \frac{1}{2}\frac{1}{2}0$; $\frac{1}{2}0\frac{1}{2}$; $0\frac{1}{2}\frac{1}{2}$.

(2) $\frac{1}{2}\frac{1}{2}\frac{1}{2}$; $\quad 00\frac{1}{2}$; $0\frac{1}{2}0$; $\frac{1}{2}00$.

Twenty-four equivalent positions:

(3) $u00; u+\frac{1}{2},\frac{1}{2},0; u+\frac{1}{2},0,\frac{1}{2}; u\frac{1}{2}\frac{1}{2};$
$\bar{u}00; \frac{1}{2}-u,\frac{1}{2},0; \frac{1}{2}-u,0,\frac{1}{2}; \bar{u}\frac{1}{2}\frac{1}{2};$
$0u0; \frac{1}{2},u+\frac{1}{2},0; 0,u+\frac{1}{2},\frac{1}{2}; \frac{1}{2}u\frac{1}{2};$
$0\bar{u}0; \frac{1}{2},\frac{1}{2}-u,0; 0,\frac{1}{2}-u,\frac{1}{2}; \frac{1}{2}\bar{u}\frac{1}{2};$
$00u; \frac{1}{2},0,u+\frac{1}{2}; 0,\frac{1}{2},u+\frac{1}{2}; \frac{1}{2}\frac{1}{2}u;$
$00\bar{u}; \frac{1}{2},0,\frac{1}{2}-u; 0,\frac{1}{2},\frac{1}{2}-u; \frac{1}{2}\frac{1}{2}\bar{u}.$

[5] P. NIGGLI. *Geometrische Krystallographie des Discontinuums*, p. 492.

[6] In the general case there are 192 equivalent positions within the unit cell of this group so that there may be as many as 192 molecules of sodium chloride within it.

[7] These results are taken from a book now being prepared for publication which contains an analytical expression of all of the special cases of each of the space groups.

Placing sodium and chlorine (or chlorine and sodium) atoms at the positions of (1) and (2) yields the "sodium chloride arrangement." The next simplest structure that can be developed is obtained from arrangement (3) by placing atoms of sodium at the 24 points corresponding to a value of $u = u_1$ and chlorine atoms at the points where $u = u_2$.

For such a structure the intensity of a reflection from a plane whose indices are h, k and l is proportional to (compare equation (1)):

$$I \propto A^2 + B^2,$$

$$\begin{aligned} A = \rho_{Na} [&2\cos 2\pi n h u_1 + 2\cos 2\pi n k u_1 + 2\cos 2\pi n l u_1 + \\ &\cos\pi n(2hu_1 + h + k) + \cos\pi n(h - hu_1 + k) + \cos\pi n(h + 2ku_1 + h) + \\ &\cos\pi n(h + k - 2ku_1) + \cos\pi n(h + k + 2lu_1) + \cos\pi n(h + k - 2lu_1) + \\ &\cos\pi n(2hu_1 + k + l) + \cos\pi n(h - 2hu_1 + l) + \cos\pi n(h + 2ku_1 + l) + \\ &\cos\pi n(h - 2ku_1 + l) + \cos\pi n(h + 2lu_1 + l) + \cos\pi n(h + l - 2lu_1) + \\ &\cos\pi n(2hu_1 + k + l) + \cos\pi n(k + l - 2hu_1) + \cos\pi n(2ku_1 + k + l) + \\ &\cos\pi n(k - 2ku_1 + l) + \cos\pi n(k + 2lu_1 + l) + \cos\pi n(k + l - 2lu_1)] + \\ &\rho_{Cl}[\text{a similar set of terms involving } u_2]. \end{aligned}$$

The B term, a similar sine expression, is not in this instance qualitatively important. When h, k and l are two odd and one even ($h = 2m + 1$, $k = 2p + 1$, $l = 2q$, where m, and p and q are any integers) or when they are two even and one odd ($h = 2m + 1, k = 2p, l = 2q$) this expression is invariably equal to zero for $n = 1$. When, however, the indices are all odd, the intensity becomes

$$A = 8\cos 2\pi u(2m + 1) + 8\cos 2\pi u(2p + 1) + 8\cos 2\pi u(2q + 1),$$

for $n = 1$. Except perhaps for very special values of u_1 and u_2, this expression will invariably have a value other than zero. In case $n = 2$ all three types of planes will give factors of appreciable value. This arrangement is consequently in entire agreement with the data *that we now possess*[8] upon which to base the *first* determination of the structure of a crystal.[9]

[8] This need be no longer true if we possessed accurate measurements of the relative intensities of the X-rays reflected from different planes of this type, *combined with* a knowledge of the positions of the electrons as the scattering centers within the atom.

[9] The agreement with the spectrometer experiments is readily shown. By substituting the appropriate values for h, k and l in expression (1), the ratio of the spacings for the (100), (110) and (111) planes in the cubic lattice is seen to be $1 : \frac{1}{\sqrt{2}} : \frac{1}{\sqrt{3}}$. Since the calculations given above have shown that the first order reflections from the first two of these planes is blotted out, the first observable reflections would occur at twice the angle of the first reflection and would consequently give apparent spacings of

$$\frac{1}{2} : \frac{1}{2\sqrt{2}} : \frac{1}{\sqrt{3}} \text{ or } 1 : \frac{1}{\sqrt{2}} : \frac{2}{\sqrt{3}}.$$

It will be sufficient for the present purpose to have pointed out a single structure for rock salt, besides the generally accepted one, which is in agreement with the experimental data. There are undoubtedly numerous others which would serve equally well. It is not, however, feasible to indicate even all of the different types of structures that would fulfill the present requirements. This arises in part from the fact that besides those other structures which can be developed from O_h^5, it is conceivable that such special values could be assigned to the coordinates of arrangements developed from other space groups that the intensity of the reflections from certain types of planes would be either obliterated entirely or would be so weak as to pass detection. As a result the sequence of spacings found for such an arrangement might agree with that for rock salt.[10,11]

The wave lengths of the X-rays calculated upon the basis of structures representing sodium chloride but possessing various numbers of molecules in the unit cell must of course differ from one another. For instance the wave lengths of the rays diffracted through the angle θ when calculated upon the assumption of the correctness of the sodium chloride structure and when calculated upon the assumption of the structure just considered which has twenty-four chemical molecules within the unit cell will stand in the ratio of $\sqrt[3]{4}$ to $\sqrt[3]{24}$.

Quantum calculations of the wave lengths of X-rays.—It was early pointed out that the quantum hypothesis furnishes an independent way of obtaining the wave lengths of X-rays. By identifying the energy of the electrons required to excite either the characteristic X-rays[12] or those of the short wave length limit of the continuous spectrum[13] (as the case may be) with the energy of the rays that are produced, it is possible from the quantum relationship

$$E = nh\nu$$

to get the frequency (ν) and hence the wave length of the corresponding X-rays.[14] If it is assumed that such X-rays correspond with the

[10] This sort of agreement with experiment is illustrated in the course of the treatment of the structure of magnesium oxide. RALPH W. G. WYCKOFF. Amer. Journ. Sci. 1: 138. 1921. (See the grouping there called (*j*).)

[11] In the light of present knowledge such a structure as we have just discussed need not be immediately disregarded as impracticably complicated, especially when it is borne in mind that it offers the chance of so placing a sodium and a chlorine atom nearer to one another than to other atoms as to preserve, in the existence of a chemical molecule, the older idea of the nature of solid sodium chloride.

[12] W. H. and W. L. BRAGG, *op. cit.*, p. 72.

[13] W. DUANE and F. S. HUNT. Phys. Rev. (2) 6: 166. 1915, etc.

[14] W. DUANE and F. S. HUNT, *op. cit.*

expenditure of a single quantum of energy ($n = 1$), as would seem probable, then the resulting wave length is in agreement with that calculated from the "sodium chloride arrangement."

The fact that it is not possible at the present time to obtain the structure of any crystal with surety without at the same time knowing the wave lengths of X-rays would consequently make it seem more logical to think of our determination of the wave lengths of X-rays (and with it all of our studies of the arrangement of the atoms in crystals) as based directly upon this quantum hypothesis, to stand or to fall with it.

Of course even this determination of the wave length of X-rays is not entirely satisfactory. For instance if, for some reason, it should seem desirable to suppose that the expenditure of two quanta of energy were required to excite X-rays, then we should have a value of the wave lengths corresponding to a structure for sodium chloride having thirty-two chemical molecules associated with the unit. Furthermore the extension of the quantum relationship from the range of light radiation to that of X-rays was indeed a large extrapolation. In spite of this, the most persuasive evidence that a satisfactory determination has been obtained is to be found in the fact that the application of the quantum relation to the limit of the continuous radiation[15] yields values for wave lengths which are in such close accord with a reasonable determination of crystal structure. This structure *happens to be* the "sodium chloride arrangement" (in the case of sodium chloride).

Summary

Taking the case of sodium chloride as typical, it is shown that there are other structures besides the commonly accepted "sodium chloride arrangement" which are in agreement with the *present* experimental data. As a result of this lack of definiteness it is emphasized that it is more logical to consider the value of the wave lengths of X-rays as based upon the quantum hypothesis.

[15] E, the energy, can be obtained from a knowledge of the voltage required to produce X-rays of the frequency ν and of the charge (e) on the electron; h is the universal constant of Planck; and n is an integer.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. The abstracts should conform in length and general style to those appearing in this issue.

OPTICS.—*Dispersion in optical glasses: II.* FRED E. WRIGHT. Journ. Opt. Soc. Amer. **4:** 195–204. 1920. (Geophysical Lab. Papers on Optical Glass, No. 29.)

In this paper proof is given that, because of the relatively short range of the visible spectrum, the substitution in a dispersion formula of the reciprocal of the refractive index, or of the excess refractivity, or by analogy of other functions of the refractive index for the direct values, leads to dispersion formulas which are fairly satisfactory. Thus, if in the two-constant Cauchy formula, $n = A + B \cdot \lambda^{-2}$ or $n - 1 = A' + B \cdot \lambda^{-2}$, the reciprocal of the refractive index or of the excess refractivity be written: $n^{-1} = C' + D \cdot \lambda^{-2}$ or $(n - 1)^{-1} = C + D \cdot \lambda^{-2}$, the new equations represent rectangular hyperbolas in case λ^{-2} is considered to be the independent variable. The last equation was recently suggested as a substitute for the Hartmann dispersion formula. A series of computations demonstrates, however, that for the crown-glasses this equation is less satisfactory than the Cauchy formula, while for the flint-glasses none of the foregoing equations is especially good. The last equation is, moreover, always less satisfactory than the Cauchy formula for computation purposes. The usefulness of the last equation appears, therefore, to be limited and less satisfactory for general application than the two-constant Cauchy formula.

F. E. W.

GEODESY.—*Modern methods for measuring the intensity of gravity.* CLARENCE H. SWICK. U. S. Coast and Geodetic Survey Special Pub. **69.** Pp. 96, figs. 26. 1921.

The measurement of gravity on land by the U. S. Coast and Geodetic Survey is made with an accuracy of about 2 or 3 parts in a million. Such accuracy with a field instrument requires more than ordinary care and skill on the part of the observer. At the present time all gravity measurements are made with pendulums only a quarter of a meter in virtual length, which are placed in an air-tight receiver and swung under a pressure of about 1/15 of an atmosphere. The cost and time required for a determination are very much less than they were and the results obtained are far more accurate than with the old types of apparatus.

This publication is primarily a working manual for field and office use. Aside from one chapter of historical data the entire book is given over to a detailed description of the instruments and to instructions for making the observations and computations. All the necessary formulas and tables are included. Sample records are shown and a sample computation for one station is carried through all the required steps.

INORGANIC CHEMISTRY.—*The binary system åkermanite-gehlenite.* J. B. FERGUSON and A. F. BUDDINGTON. Amer. Journ. Sci. **50:** 131–40. 1920.

The binary system åkermanite ($2CaO.MgO.2SiO$)-gehlenite ($2CaO.Al_2O_3.SiO_2$) was studied by the quenching method and the solidus and liquidus curves were determined. The system forms a complete series of solid solutions with a minimum melting-point about 70° below the melting-point

of åkermanite, the component of lower melting-point, at a composition of about 74 per cent åkermanite and 26 per cent gehlenite.

The densities of crystals and glasses of åkermanite, gehlenite, and several intermediate mixtures were determined and found to confirm the isomorphous character of the system. Åkermanite was found to show the unusual feature of its glass having a greater density than the corresponding crystals at 25° C. This peculiar character is checked by the indices of refraction for glass and crystal, respectively, the index of refraction of the glass being greater than the maximum index of the crystal.

The optical characters of the crystals are a continuous function of the composition. In optical characters åkermanite is positive and gehlenite is negative. Crystals of certain intermediate compositions are isotropic for light of a definite wave length and constitute a transition phase between positive and negative crystals. J. B. F.

GEOLOGY.—*Mining in the Matanuska coal field and the Willow Creek district, Alaska.* THEODORE CHAPIN. U. S. Geol. Survey Bull. **712-E.** Pp. 46(131–76). 1920.

This report describes developments in the Matanuska coal field up to the end of 1918 and records some recently acquired knowledge of the structure and stratigraphy of the coal-bearing rocks and the character and persistence of the coal beds, details of which are becoming more apparent with the opening of the underground workings. The areal distribution, character, chemical analysis, steaming and coking quality of the coal are discussed, stratigraphy and structure of the region are described, and the mining developments depicted. R. W. STONE.

GEOLOGY.—*Mining in northwestern Alaska.* S. H. CATHCART. U. S. Geol. Survey Bull. **712-G.** Pp. 14(185–98). 1920.

Discusses the adverse conditions which caused greatly decreased mineral production in Seward Peninsula in 1918; describes the use of cold water in thawing perpetually frozen muck and gravel and its application to placer mining. Tungsten and platinum were produced, but wholly incident to the mining of placer gold. A small quantity of coal was mined, and drilling for oil in a locality where the hard rocks are granite and schist was unsuccessful. R. W. STONE.

GEOLOGY.—*The Mogollon district, New Mexico.* HENRY G. FERGUSON. U. S. Geol. Survey Bull. **715-L.** Pp. 34(171–204). 1921.

The Mogollon or Cooney district is in the southwestern part of Socorro County, New Mexico, about 14 miles from the Arizona line. The rocks of the district are nearly all lavas, or sedimentary rocks composed of materials derived from lavas. Flows of rhyolite and andesite, together with sedimentary and pyroclastic rocks, had reached a total thickness of several thousand feet when faulting of considerable magnitude took place and the region was broken up into irregular blocks bounded by normal faults. The faulting was closely followed by the introduction of mineral-bearing solutions, which followed channels determined by the previous faulting, so that practically all the faults are the sites of veins.

The ores of the district are valuable mainly for silver. Argentite, pyrite, bornite, chalcopyrite, and tetrahedrite, together with small amounts of horn silver and native silver, are the principal ore minerals. The ores are principally sulfides and give evidence of being in part due to enrichment, although

the relative importance of secondary processes has not yet been fully determined. R. W. STONE.

GEOLOGY.—*Potash resources of Nebraska.* W. B. HICKS. U. S. Geol. Survey Bull. **715-I.** Pp. 15(125–39). 1921.

Describes the location, area, and probable potash content of the alkali lakes in the sand-hill region of Nebraska, and discusses the composition of the brine and origin of the potash. R. W. STONE.

GEOLOGY.—*Mineral resources of the Goodnews Bay region, Alaska.* GEORGE L. HARRINGTON. U. S. Geol. Survey Bull. **714-E.** Pp. 22(207–28). 1921.

The Goodnews Bay region as here considered embraces the territory lying south of Arolic River and draining into Kuskokwim Bay, Alaska. In many respects this region is one of the most inaccessible in Alaska for a small expedition. For a number of years it has been necessary to come overland from the Yukon either by the portage or by way of Iditarod, or to travel in a kayak or canoe, or by small schooner or sailing boat from Togiak.

The sedimentary rocks comprise limestone, argillite, sandstone, and conglomerate, and the metamorphosed equivalents of most of these. A considerable variety of igneous rocks is also found, including basalt flows, dikes that were taken in the field to be andesites, and intrusive granites, with some massive intrusives that are probably intermediate in composition between the granite and the basalt. A large part of the region is covered by unconsolidated deposits of alluvial, glacio-fluviatile, and marine origin.

Gold placer mining is the principal interest. The original deposition of the gold in fissures associated with quartz was probably genetically related to the intrusion of the late Mesozoic granites into the sedimentary and earlier igenous rocks, which range from Paleozoic to probably late Mesozoic in age. From the original deposits the gold has been eroded by streams and other agencies, not including glaciation, and has been concentrated in placers by some streams, mainly those in the vicinity of the granites. Glacial erosion has removed most of the gold-placer deposits and has scattered the gold widely over a considerable area in amounts not suitable for profitable mining.

Postglacial concentration has been effected by some streams in connection with the erosion of the rocks containing auriferous veins. R. W. STONE.

GEOLOGY.—*Potash deposits in Spain.* H. S. GALE. U. S. Geol. Survey Bull. **715-A.** Pp. 16, pls. 3, figs. 3. 1920.

Potash was discovered in Spain in 1912, during an attempt to open a salt mine near Suria, Province of Barcelona. Evidence gained in a shaft and several borings convinced local engineers that the deposits contain 200,000,000 tons of pure potash (K_2O), and in 1918 a mine shaft and a refining plant were begun. The shaft is located near the axis of an anticline, in a zone of intense folding, and the potash and associated salt beds are probably much contorted; such contortions are seen in the beds in the crest of the anticline at Cardona, 8 miles distant, where salt is extensively mined. The evidence of the existence of potash in the Cardona deposits, however, is not very definite, and information as to the occurrence in the surrounding region is meager. Many concessions for prospecting and exploitation in an area of 400 square miles have already been granted, and the Government has re-

served about 1800 square miles for future exploration. Restrictive legislation, as outlined in this paper, somewhat hampers activities in the district. The prospects indicate an output of potash ample for Spanish needs, but no judgment can yet be ventured as to the influence of the Spanish field on the world market. J. D. SEARS.

CERAMICS.—*Note on the motion of the stirrers used in optical-glass manufacture.* E. D. WILLIAMSON and L. H. ADAMS. Journ. Amer. Ceramic Soc. **3**: 671-677. 1920. (Geophysical Lab. Papers on Optical Glass, No. 25.)

Perhaps the most noticeable difference between the manufacture of optical glass and that of other types of glass (bottle, window, and plate) is that the melt must be stirred vigorously in order to get complete mixing. The reason behind this necessity is the close approach to homogeneity specified in the tests to be passed by the finished article. The stirrers used are necessarily of a very simple nature, generally consisting of a clay rod attached at right angles to an iron water-cooled pole, the other end of which is driven at steady speed in a horizontal circle, while supported near the center by a pulley or other support. Such a device does not cause circular motion of the stirring-rod, but causes it to describe an egg-shaped figure at a variable speed. A slightly more uniform motion is obtained if a pin attached to the pole slides in a fixed slot instead of the pole passing over the pulley, but the general results are not very different. If the support is not close to the center of the pole, the motion of the rod is far from circular and a large part of the glass in the pot is not stirred. E. D. W.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

ANTHROPOLOGICAL SOCIETY

548TH MEETING

The 548th meeting of the Society was held at the United States National Museum on October 26, 1920, at 4.45 p.m. Dr. ALES HRDLICKA, curator of physical anthropology, U. S. National Museum, addressed the Society on *The anthropological problems of the Far East and the Pacific.* The lecture was carefully prepared and dealt with a subject with which Dr. Hrdlicka was most familiar both because of long study and recent field work. The paper was discussed by Mr. HOLMES, Mrs. ZELIA NUTTALL, Dr. MICHELSON, and Dr. SWANTON.

549TH MEETING

At the 549th meeting of the Society, held at the National Museum at 4.45 p.m. on November 16, 1920, Mr. SYLVANUS G. MORLEY, Associate of the Carnegie Institution of Washington, addressed the Society on *The hieroglyphic writing of the ancient Mayas.* Mr. Morley illustrated his excellent presentation with charcoal drawings of the glyphs. At the conclusion of Mr. Morley's lecture, Mr. W. E. GATES, of Baltimore, gave an interesting and enthusiastic talk of ten minutes on the subject of Maya writing, and told especially of recent progress which he has made in the deciphering of color symbols, to which Mr. Morley had referred in his talk.

550TH MEETING

The 550th meeting was held in the National Museum at 4.45 p.m. on December 14, 1920, and had as program an illustrated lecture by Mr. S. D. BULLOCK, of the Bureau of Plant Industry, Department of Agriculture, entitled *Ten years among the Araucanians of Chile.* Mr. Bullock has lived for ten years among the Araucanian Indians of the vicinity of Valdivia, Chile, as industrial teacher of the Indians, and knows them and their customs intimately. At the close of the lecture Mr. Bullock exhibited some Araucanian costumes and other objects. Questions were asked by Lieut. W. E. SAFFORD and others.

551ST MEETING

The 551st meeting was held at the National Museum at 4.45 p.m. on January 18, 1921. Mr. WILLIAM E. MYER, of Nashville, Tennessee, gave an interesting lecture on *Recent explorations in the Cumberland Valley, Tennessee,* being an account of archaeological field work done by him in 1920 for the Bureau of American Ethnology. The talk was illustrated by lantern slides. The lecture was discussed by Dr. FEWKES and others.

552D MEETING

The 552d meeting was held at the National Museum at 4.45 p.m. on February 8, 1921. Lieut. W. E. SAFFORD, of the Department of Agriculture, spoke on *Old and new Samoa.* The lecture was illustrated by original slides. Lieut. Safford made his first visit to Samoa on the U. S. Ship *Mohican* in 1888, before Robert Louis Stevenson came to the islands, and made a second visit in 1899, two years after Stevenson's death. The lecturer spoke throughout from first-hand information. At the close of the lecture there was a discussion by Dr. HOUGH, Mr. HOLMES, and others.

553D MEETING

At the 553d meeting, held at the National Museum at 4.45 p.m., March 21, 1921, Dr. J. WALTER FEWKES, Chief of the Bureau of American Ethnology, spoke on *The fire temple of the Cliff Dwellers.* The ruin of the Fire Temple was excavated by him in the Mesa Verde National Park, Colorado, during the summer of 1920. The lecture was beautifully illustrated by slides. It was discussed by Dr. HOUGH, Mr. HOLMES, and others.

554TH MEETING

The program of the 554th meeting, held at the National Museum at 4.45 p.m., March 22, 1921, was a paper by Mr. G. N. COLLINS, of the Department of Agriculture, on *The origin and early distribution of maize.* Mr. Collins agrees on the whole with Harzberger, who advocated the theory that maize has been hybridized with some other close relative, but puts the relationship a little further off—for genetic reasons. The paper was discussed by Dr. HOUGH, Prof. HITCHCOCK, Lieut. SAFFORD, Mr. LA FLESCHE, and others.

555TH MEETING

The 555th meeting of the Society was held in conjunction with the Medical Society of the District of Columbia, at the new home of the latter at 1718 M Street, N. W., on April 5, 1921, at 8.00 p.m. Dr. GEORGE M. KOBER presented as address of the retiring president of the Anthropological Society of Washington, 1920, a paper entitled *A plea for the prevention of permanent disabilities in childhood.* In pursuance of the established custom of the Society, there was no discussion of this paper, it being a presidential address.

556TH MEETING

The 556th regular meeting (42nd annual meeting) of the Society was held at the National Museum at 4.45 p.m., April 19, 1921. Dr. C. HART MERRIAM, President of the Society, delivered a lecture on *The Indians of the Yosemite Region, California*. The lecture was illustrated by a large number of slides showing the distribution of the dialects of the stock, the history of the Indians, the landmarks of the region, and the present survivors. At the close of the lecture the annual meeting of the Society was held.

The Secretary, JOHN P. HARRINGTON, reported that the Society has at present 51 active members, 6 life members, 4 associate members, and 2 honorary members, making a total membership of 63. New members added during the year were: MR. W. E. MEYER, MR. M. J. CAPLES, Mr. R. E. MONTGOMERY, and MISS ELLEN HAYES. One active member was lost through death: Dr. EDWIN LEE MORGAN. The Treasurer's report showed a balance to the credit of the Society of $139.56, and total assets of $667.47.

The following officers were reelected for the ensuing year: *President*, C. HART MERRIAM; *Vice President*, NEIL M. JUDD; *Secretary*, JOHN P. HARRINGTON; *Treasurer*, J. N. B. HEWITT; *Board of Managers*, CHARLES L. G. ANDERSON, FELIX NEUMANN, FRANCIS LA FLESCHE.

JOHN P. HARRINGTON, *Secretary*.

SCIENTIFIC NOTES AND NEWS

The topographic survey of the Virgin Islands was completed by the U. S. Coast and Geodetic Survey in June.

An interdepartmental conference was held on July 25 at the Interior Department to discuss the status of patents arising within the government service. The purpose of the conference was to coordinate and formulate the views held in the various bureaus and departments on this subject. After discussion, a committee of five was appointed to report in detail ways and means for the suggested coordination, and another committee of three was appointed to develop a plan for a general clearing house of information for the departments with respect to licenses, shop rights, and titles in patents which the Government has acquired or may acquire.

Mr. WALTER G. CAMPBELL was appointed acting chief of the Bureau of Chemistry in August.

A geological party of four, consisting of Professors R. A. DALY and CHARLES PALACHE of Harvard University, Professor G. A. F. MOLENGRAAF of the University of Delft, Holland, and Dr. F. E. WRIGHT of the Geophysical Laboratory, Carnegie Institution of Washington, will spend the coming winter in southern Africa, in a geologic and petrologic study of the Bushfeld igneous complex in Transvaal.

Dr. H. C. DICKINSON, chief of the automotive investigations division of the Bureau of Standards, has been granted a leave of absence to become director of research for the Society of Automotive Engineers. He will continue to assist in the work of the Bureau in a consulting capacity.

Dr. GRAHAM EDGAR, professor of chemistry at the University of Virginia, has been associated with the Fixed Nitrogen Research Laboratory at the American University during the summer, completing some work which he began there during the War.

Major LOUIS ALBERT FISCHER, chief of the division of weights and measures of the Bureau of Standards, died on July 25, 1921, in his fifty-eighth year

Mr. Fischer was born in Washington, D. C., January 4, 1864. He was educated at George Washington University, and afterwards joined the staff of the U. S. Coast and Geodetic Survey, where he was in charge of the office of weights and measures, the forerunner of the present Bureau of Standards. He took an active part in the organization of the Bureau in 1901, and had been in charge of its special division on standards of length, volume, and mass since that date. He was a leader in the movement to promote uniform standards of weights and measures in the States and municipalities of the country. He was a member of the ACADEMY, past president of the Philosophical Society, and chairman of the Washington Section of the American Society of Mechanical Engineers.

Dr. F. E. MATTHES, of the U. S. Geological Survey, has been spending the summer in exploration of the crest of the Sierra Nevada as far south as Kings River Canyon, in search of data on the earlier glaciation of the region.

Mr. J. D. NORTHROP has been reinstated as geologist in the U. S. Geological Survey, and has been assigned to duty in the mineral division of the Land Classification Board.

Dr. T. OKADA, director of the recently established Imperial Marine Observatory at Kobe, Japan, visited the scientific institutions of Washington in August.

Prof. J. F. ROCK returned in June from an eleven months' exploring trip through remote parts of Siam, Burma, Assam, and Bengal for the U. S. Department of Agriculture. He showed the Botanical Society on June 27 the first photographs ever exhibited of the tree, *Taraktogenos kurzii*, in its native habitat. The seeds of this tree are the source of chaulmoogra oil, a remedy for leprosy, and Professor Rock secured enough of the seeds to assure the establishment of a plantation of the tree in Hawaii.

Dr. J. H. SHRADER, formerly with the Bureau of Chemistry, U. S. Department of Agriculture, became director of the bureau of chemistry and food of the Health Department of Baltimore on July 1.

Dr. GEORGE OTIS SMITH, director of the U. S. Geological Survey, attended a meeting on July 20 in London as a member of the organization committee of the International Geologic Congress.

Dr. W. W. SKINNER, chief of the water and beverage laboratory of the Bureau of Chemistry, has been appointed assistant chief of the Bureau.

Mr. R. S. TOUR, chemical engineer of the Nitrate Division, Ordnance Department of the Army, has been appointed dean of the department of chemical engineering at the University of Cincinnati.

Dr. TSAI, chancellor of the National University of Peking, China, visited the scientific institutions of Washington in June.

Mr. ROSENDO VARGAS, a member of the Taos tribe of Indians of New Mexico, has been assisting Mr. J. P. HARRINGTON of the Bureau of Ethnology in the study of the ethnology of the tribe. Mr. Vargas is at present an employee of the office of Indian Affairs, Department of the Interior.

Mr. C. J. WEST has resigned as director of the information department of A. D. Little, Inc., of Cambridge, Massachusetts, to become managing editor of the Tables of Physical and Chemical Constants now being compiled under the joint auspices of the National Research Council, the American Chemical Society, and the American Physical Society.

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